

Remarks

In view of the foregoing amendments and these accompanying remarks, it is respectfully requested that this application be reconsidered.

Claims 1-14 are hereby canceled without prejudice and new claims 15-25 are now presented. These claims are believed to more particularly point out and distinctly claim the subject matter herein. Further, new independent claim 15 does specifically set forth positive steps for effecting the method. Therefore, it is believed that the rejection under 35 USC 112 has been obviated and it is requested that this rejection be withdrawn.

Applicant has considered the prior art rejections and the cited references to Liu (US Patent 5,685,993), Watson (US Patent 4,940,550) and Cort (US Patent 6,896,815) and respectfully disagrees with the conclusions of the Examiner.

Before commenting on the office action Applicant wishes to first emphasize the inventive concept of the claimed method for removal of heavy metals from an aqueous solution. The present method is based on precipitation of metal-ferrite compounds, which are then separated from the solution. These metal-ferrite compounds are formed after the pH of the solution is preferably adjusted to 8-10 by adding of OH ions. The formation of metal-ferrite compounds is carried out in the presence of a magnetic field and in the presence of a chemically active iron ferrite seed. Under these conditions, the metal-ferrite compounds precipitate and, since these compounds are magnetic, they can be conveniently separated from the solution by a magnet.

The advantage of direct precipitation of metal ferrites, as opposed to the gradual conversion of hydroxides to ferrites, is two fold:

1. The process is much quicker,
2. The chemical demand is much lower, drastically reducing the cost of the process, and the salt content of the treated liquid.

The advantage of binding the contaminant metals into metal -ferrites compounds lies in the fact that metal-ferrite compounds are chemically stable and, for disposal purposes, can be considered as non-hazardous waste. They have high density and are crystalline. Therefore, they can be more reliably and more rapidly separated from the solution, as compared with the known removal methods, which are based on the formation of hydroxides of contaminant heavy metals. The hydroxides are more soluble than ferrites and the precipitate is amorphous and difficult to separate from the liquid. Therefore it would be desirable to devise such a removal process, which would not involve formation of hydroxides of the contaminant metals.

It has been unexpectedly empirically revealed that, despite the presence of OH ions in the aqueous solution, one can catalyze formation of the metal ferrite compounds and inhibit formation of the hydroxides. This becomes possible if the precipitation process involving formation of the metal-ferrites compounds is accompanied by exposing the contaminated aqueous solution to a magnetic field and if a chemical seed is present in the aqueous solution.

By virtue of the immediate formation of the insoluble metals-ferrite compounds without the intermediate formation of hydroxides, the whole process becomes more efficient, more economical and more technically feasible. Furthermore, the achieved residual metal ion concentration levels in the aqueous solution are extremely low.

Neither Liu nor Watson contains any implicit or explicit teaching, suggestion or incentive, which support the desirability or even possibility for the combination of their teachings.

The Liu process does not employ the immediate formation of insoluble ferrites (as in the present invention), but, rather, the gradual conversion of hydroxides to ferrites. This can be seen from those excerpts from the description, which refer to the Mechanism I and Mechanism II (see column 2, lines 20-36). Furthermore, Liu does not disclose or suggest exposing the solution to a magnetic field during formation of the insoluble compounds.

In the herein disclosed and claimed Invention, a magnetic field is employed as a catalyst for the direct precipitation of metal ferrites without the intermediate formation of metal hydroxides. In the Liu process, the metal ions are first precipitated as hydroxides and then are gradually converted to ferrites. Applicant's single step process has very definite cost advantages and this is an important difference between its work and that of Liu. The fact that ferrites are generally magnetic may be an added advantage for the purpose of separating a solid magnetic phase from a liquid phase. However, the magnetic properties of ferrites are certainly not an advantage of the direct ferrite precipitation process.

In Applicant's view Liu lacks all the inventive features of the herein claimed invention.

Liu uses a magnetic field only as an aid for separation of the solid phase from the liquid phase. This feature separates the herein claimed invention from Liu. It further explains the economic advantages of our patent.

A more detailed analysis of the Liu patent data follows so as to compare the economic advantages as described in the instant patent application as compared to the Liu patent. For this purpose Applicant analyzed the data in Liu example 5. This example is chosen as it is the only example in the patent where the dissolved heavy metals in the water requiring treatment are effectively removed.

Regarding iron consumption, Liu states that in his process "the molar ratio iron to heavy metals is greater than 3". However, analysis of his data reveals a ratio closer to 30. The composition of the synthetic wastewater used by Liu is shown in the following table

TABLE 1 Liu Synthetic Waste Water Composition

El	Ppm	Molar conc. ($\times 10^6$)
Pb	1.5	7
Cd	8.0	71
Ni	3.3	56
Cu	8.5	163
Al	50	1850
Cr	98	1540
Mn	137	2500
Zn	100	1530
Tc	406.3	7720

The chemical flows used by Liu during the treatment process are listed in the following table

TABLE 2. Chemical Flows Used By Liu

chemical	gm/min	Liters/min	Solu conc. (molar)	Moles/min	Moles chemical/ mole heavy metal
Wastewater		3.785	7.72×10^{-3}	29.2×10^{-3}	
FeSO ₄	120 (avg)			.79	27
NaOH		.130	8	1.04	35
Air	55			3.9	130

We now look at the corresponding data for Applicant's process using example 6

TABLE 3. Applicant's Synthetic Waste Water Composition

Element	Ppm	Molar conc. ($\times 10^6$)
Cr	140	2692
Ni	20	341
Zn	50	764
Total heavy metal	210	3797
Total Fe	198	5370

Applicant's chemical flows are shown in the following table

TABLE 4. Applicant's Chemical Flows (Example 6)

Element	Liters/hour	Solu. Conc. (molar)	Mole/hour	Moles chemical/ Mole heavy metal
wastewater	1	3.797×10^{-3}	3.797×10^{-3}	
NaOH	4×10^{-3}	3.12	12.5×10^{-3}	3.30
Fe (added)	1	5.370×10^{-3}	5.370×10^{-3}	1.42

TABLE 5. Comparison Of Chemical Requirements

Moles chemical/ mole heavy metal	Liu process	Applicant process	Liu Process/ Applicant process
Fe	27	1.42	19
NaOH	35	3.30	10.6
Compressed air	130	0	

Thus it can be seen that the iron requirements in Applicant's process are 19 times less and the NaOH requirement is more than 10 times less than in the Liu patent. In terms of direct chemical costs, handling costs and disposal costs, the chemical requirements specified by Liu are beyond the realm of economic feasibility.

Another advantage of Applicant's process resulting from the combined use of magnetic seed and magnetic field is the increased reaction speed. It should be pointed out that in the herein patent application (example 3) times of 15 minutes are mentioned, as opposed to the 50-60 min mentioned by Liu. Again for a realistic application of the process, rates are of critical importance

Watson mentions using a magnetic field for the attraction of magnetic particles, thereby causing them to form a compacted sludge. This magnetic field is not intended for catalyzing the formation of insoluble compounds (as in the present invention).

This patent appears irrelevant as it deals only with a mechanism for concentrating sludge, containing a high concentration of magnetic particles in a waste solution, and has nothing to do with the technology of ferrite precipitation, which is the subject of the herein claimed invention. The importance of ferrite precipitation is related to very low residual heavy metals remaining in solution after ferrite precipitation, the ease of separation of the ferrite precipitate due to its density and crystalline structure, and the chemical stability of the ferrite compounds.

Therefore, it is believed that a combination of Liu and Watson does not render the herein claimed invention obvious and, therefore, it is respectfully requested that the rejection under 35 USC 103 be withdrawn.

As to the rejection that a combination of Liu with Watson and with Cort renders some of the subject matter obvious, none of the three references contains any implicit or explicit teaching, suggestion or incentive, which supports the desirability or even a possibility for the alleged combination. Cort mentions the use of magnetic separation and magnetic seed material, which assist during the separation step, but not during the step when insoluble compounds are still being formed and precipitated (as in the present herein claimed invention).

In Cort, a magnetic field and magnetic seed particles are employed solely as an aid to the separation of a magnetic solid phase from the wastewater. The magnetic field is not involved in initial precipitation of the hydroxides and sulfides. Ferrite precipitation is not discussed at all in the patent. Therefore, it fails to teach or even suggest the claimed features of the herein invention.

Therefore, it is believed that a combination of Liu, Watson and Cort does not render the herein claimed invention obvious and, therefore, it is respectfully requested that the rejection under 35 USC 103 be withdrawn.

Therefore, all the pending claims are novel over the cited prior art and not anticipated or obviated, and the rejections under 35 USC 103 should be withdrawn.

It is, therefore, requested that a Notice of Allowance issue and that all of the pending claims be allowed.

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Respectfully submitted,

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